

Price vol 15

nº 6490

AN
ESSAY
FOR THE
CONSTRUCTION
OF
ROADS
ON MECHANICAL and PHYSICAL
PRINCIPLES.



L O N D O N :

Printed for T. DAVIES, in Great Ruffel Street,
Covent Garden.

M, DCC, LXXIV.

ESSAYS

CONSTITUTION

NO. 1

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UNITED STATES



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P R E F A C E.

*To Mr. DAVIES, Bookseller, in Russel-
Street, Covent-Garden.*

S I R,

***E**LABORATE Prefaces are
often like a fine Sign to a bad Inn :
Such shall not be mine : All I will say
is, that the following Discourse is upon
a Subject which, though in universal
Practice, has not yet, I believe, been
reduced to first Principles, and treated
in a philosophical Way. 'Tis the Pro-*

B

duction

*duction of an ingenious Friend of mine,
who wishes to throw in his Mite to
the public Good, independant of the
Views of either the Fame, or the
Profit, of Authorship: The Concealment
of his Name proves the One; you can
vouch the Other. Print it as soon as
you please; and if the Profit pays your
Trouble, it will give him an additional
Satisfaction, as well as,*

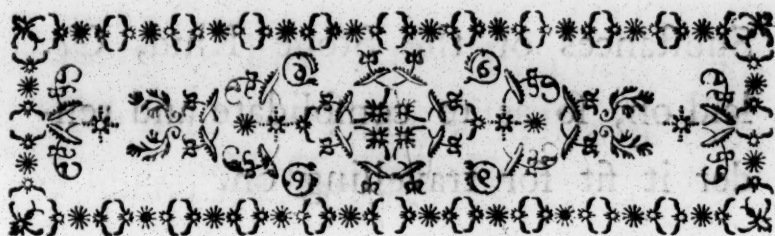
S I R,

Your Friend,

And humble Servant,

LONDON,
Mar. 1, 1774.

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ESSAY

On the CONSTRUCTION of

ROADS.

WHEN the Subject of a Road is treated of, it ought to be understood, to be under two distinct Heads, viz. that of the *Foundation* part; and that of the *Superstructure* or Covering. The former includes the intended Line of Road, with the side Trenches, and under Drains, with the Surface made equal. The latter;

B 2

Substances

Substances of the Stone Kind, &c. laid on, so as to consolidate and render it fit for travelling on.

There is scarce a Doubt, that the Construction of a Road, must depend on mechanical and physical Principles. Whether it has been hitherto viewed in this Light, has not come to my Notice. The public Utility of the Subject, assuredly demands Investigation. *Road making* seems to be far from so simple an Operation, as it is oft imagined; too many Testimonies there are, to evince this; it is complicated. To bring it to perfection, requires (as all other Arts do) the Aid of Science, to discover Causes and Effects; that wide extended
Range

Range of Ideas ; that Propriety, Discernment and Taste, which arise from a liberal Education.

It is with Diffidence, as well as Deference to superior Abilities, that I have ventured to make a few cursory Observations ; merely with the View of rousing the Attention of those, who are much more qualified to discuss the Subject in a masterly Manner, and to draw it out into such plain practical Rules, as may be accommodated to the Capacities of those, who are little versed in higher Speculations. I should even be happy to find my Conjectures disproved ; and Hypothesis more rational and just, substituted in their Room.

ACTION

ACTION *and* RE-ACTION
are equal and contrary.

On this Axiom, rests the Idea of a perfect Road. It is obvious, that a well constructed Road must be framed so as to have the Pressure and Resistance of it's several Parts to counteract, to counterpoise, and to unite in one compacted Body.

From this Outline, we see it's Resemblance to the Properties of the Section of an Arch ; where, conceive right Lines proceeding from the Periphery to unite in one common Centre ; and each Line is perpendicular to it's respective Surface.

Rays

Rays of Light passing through a convex Lens, and converging in a Focus, may at one View, exhibit a Picture of this.

Imagine this Representation to be a Machine of Timber. The Laws of Gravity, are perfectly kept up, in the Weight being perpendicular ; and the Union at the Centre (a firm Base, and side Supports supposed) constitutes a Resistance; equal to the incumbent Pressure on the Arch ; together with all the Powers above recited, of a proper constructed Road.

An Arch of Stone, whose Materials are properly adjusted in their Shape, preserves the like Powers, on the same Principles.

The

The Above is the most stable Form, when the constituent Parts are large, and put together in a regular and artificial Manner; but in a Road where the various Parts are small and irregular, they are prone to yield, and leave the right Line of Direction; one Part, by giving Way, quits the Perpendicular; makes a lateral Pressure, and affects the whole.

This elevated Form, both from the Laws of Mechanism, and being improper for the Uses of a Road, is to be laid aside; and another of a less critical Shape must be chosen; such as the Section of an Ellipse. Nay, admitting the Surface of a Road to be very little more than rounded (as is
oft

oft found eligible) nevertheless, taking in the Foundation; it is prefumable, the whole Strength and Stability will depend on the Principles of an Arch.

To illustrate this,—Put a little Ball into a Vessel with a narrow turned-up Edge or Brim, and immerse so much of it in Paste, or any other thick Consistence, as will keep it upright; press the upper Surface of the Ball, in a Space of about ninety Degrees, with a concave Body to answer the Shape of it; and the whole Pressure will be found as perpendicular in one Point, on the opposite Side or Pole of the Ball: So far this agrees with the aforesaid Definition of an Arch. Take as

C many

many of these Balls, as will fill the Vessel, or rise above the Level; give uniform Compression to the whole Surface of them; they will then combine together; and from a perpendicular Power, (supported by a lateral Aid of Pressure and Resistance from the Bottom) they will unite as so many joint Arches, and form a stable Counterpoise, and act as one solid Body; Action equal to Re-action; one Power ballancing another.

Suppose a Road to be covered entirely with Gravel, these Pebbles are generally found to be of a globular or roundish Figure: Such, having their Interstices fitted with a finer Gravel or Sand, as also Earth, will all (when
opposed

opposed or hemmed in, by the out Verge of the Road) act together, and combine, like the Balls, &c. in one general uniform Mass, upon the Principles of a regular constructed Arch, though not so mathematically just; and it will be less so, where the Gravel has too much Earth in it; or when it is made with Stones, which must be angular though ever so finely broke.

It might be further asserted, that the Failure or breaking up of a Road, is chiefly owing to a Deviation from the above Principles of an Arch. To reason on this Head, is unnecessary; reverse the Rules of just Proportion, and it appears obvious.

So much, it is presumed, will suffice to throw some Light on the Point aimed at.

In the Structure of a Road, peculiar Attention is to be paid to the Foundation Part; here must lie that Counterpart, that uniform proper Resistance which is to support the upper Fabrick. The Difference of Soils is to be carefully examined; what their various Qualities, and by what Measures the proposed End may be gained; having this for ever in your eye; that the Density and Elasticity of *this* Part, must correspond with the other or *Superior*.

When

When a Road is to be made with Accuracy, it ought to be first (as the Term is) *formed*; that is, it should have proper side and under Drains made; and the Earth which has been employed in Vegetation, as much stript off the Surface as may be convenient, made even, &c. and in this State, should remain some time to drain, and subside, and each Part to find it's proper Gravity and Poise, before the other Materials are laid on. How long it is to continue uncovered, must depend on the Nature and Texture of the Soil, and the Season of the Year, &c. for Instance, if it should be a Clay: this Substance is very tenacious and cohesive, not ready to take in Water, and averse to quit with it; and for these

these Reasons, has a native Spring and Elasticity, beyond any other. It ought to be no further drained than to take off the superfluous Wet, which else would undermine it, would carry away part of that viscid Substance, and leave empty Spaces in it, which would in Time, occasion the Surface to fall in, and of Course the upper Materials. If exposed too long to the Air before covered in, Draught and Sunshine make partial Cohesions and the Clay separates; and into these Chasms future Rains enter. From the vitriolic Acid this Substance abounds with, it attracts the Salts from the Atmosphere, together with the finer Particles of Earth mixed with Rain and Dews. A Quantity of Air it is replete with

with, which was formerly in a fixed State, and furrounded by thin Cafes of Clay, forming fo many native Springs, now expands violently, and like fo many little Mines tear the exterior Matter to pieces.

From all thefe Reafons, it would foon become of a fertile Nature, and rendered lefs fit for the Purpofes of a uniform compacted fpringy Body, able to bear up againft the incumbent Arch of the Road.

Should the Soil be of any of the rich Loams. Such have but little native Spring in them, and are rather unfavourable; but to remedy this Defect, let the intended Line be plough-
ed

ed or dug ; and when the Drains, &c. are made, give it a thin Coat of a fine homogeneous Substance, such as Sand : here the Density is proportioned, and the Pressure of it equal ; the Sand will incorporate with the Earth, will absorb rising Moisture ; and on being rolled, will form a pretty consistent Foundation for the upper Covering of Gravel.

If a gravelly Bottom is found, the Business is half done, a natural Arch is already found to place the others on.

When Moss Bog is in the intended Line of Road, and too deep to be removed, the Drains must be cut so deep as to drain off all the superfluous
Wet

Wet from below the very Foundation; when the Moss must be allowed Time to subside, before the upper Part is begun to be made; it has generally a tough Kind of matted Surface, formed by the Roots of Plants, which grow from Earth and Salts, collected from Rains and the Atmosphere; if on this Mass, Sand or fine Gravel is laid, it will have a like salutary Effect, as in the former Case of Loams: Boughs of Trees are expensive, and are unfit for a great Repair of heavy Carriages. Being left too long uncovered it will turn too dry, and have it's elastick repulsive Spring lessened.

D

Moss

Moss is a Substance of a peculiar Texture, and is generally acknowledged to be composed of rotten Vegetables ; how it came into this State seems not to be intelligibly accounted for, without supposing it owing to subterraneous Collections of Water, whose diffusive Moisture has (in the Course of Ages) caused such Changes : on this Presumption, what Reason is there to guard against a latent Enemy by deep under Drains ? These rotted Vegetables seem to retain the heavy essential Oil of the denser Parts of the Plant, together with a fine Earth, from the putrefied Leaves. This Oil is minutely divided and surrounded, as in little Bags, by the Particles of Earth and Water to which it strongly adheres,

adheres, and like so many Puff-Balls form a collective Multitude of Springs, all uniting in one elastick Body; in this State it resists the Oscillations of the internal Air, by which it preserves many Substances from Putrefaction: It also seems to possess the Power of assimilating contiguous Earths into it's own Substance; whether they are below its original Bottom, or have fallen on it's Surface, in Rains, &c. from this gradual Increase of Bulk, it perhaps may have been said to grow, somewhat like to Vegetation. Observe from this, how soon a Road may break down, if Drains are not attended to, and the Surface not frequently repaired.

Is granted, that the above Rules (supposing them to be just) cannot be easily or minutely executed ; nay, from Circumstances of Want of Time, Seasons, &c. perhaps not practicable in their full Latitude. The ingenious Artist, nevertheless, on whatever Subject employed, ought constantly to have in his Eye, at least, the ideal Model of Perfection ; and in the Execution to come as near it as possible ; a few Out-lines derived from Truth and Nature being laid down, the Judgment is directed towards certain leading Points ; and Discretion may (from Necessity) deviate prudentially,

The Foundation of a Road being judged so essential a Part, and it's being

ing feared, so often overlooked, occasioned such a Precision of Detail.

It appears a **Mistake** to make a Road more raised in the Middle, than just a little more than will allow the Rain Water to glide gently off the Surface: if raised higher, the Water will acquire such a Velocity as to be Superior to the Weight of the finer Gravel, and wash it down with it into the side Trenches; a Descent of two Inches to a Mile to enable Water to run, may give it a Sort of comparative **Idea**, how small a Declivity may answer the purpose of a Road.

When a Road is raised too high, it suffers much in Waste of Gravel from
Wind,

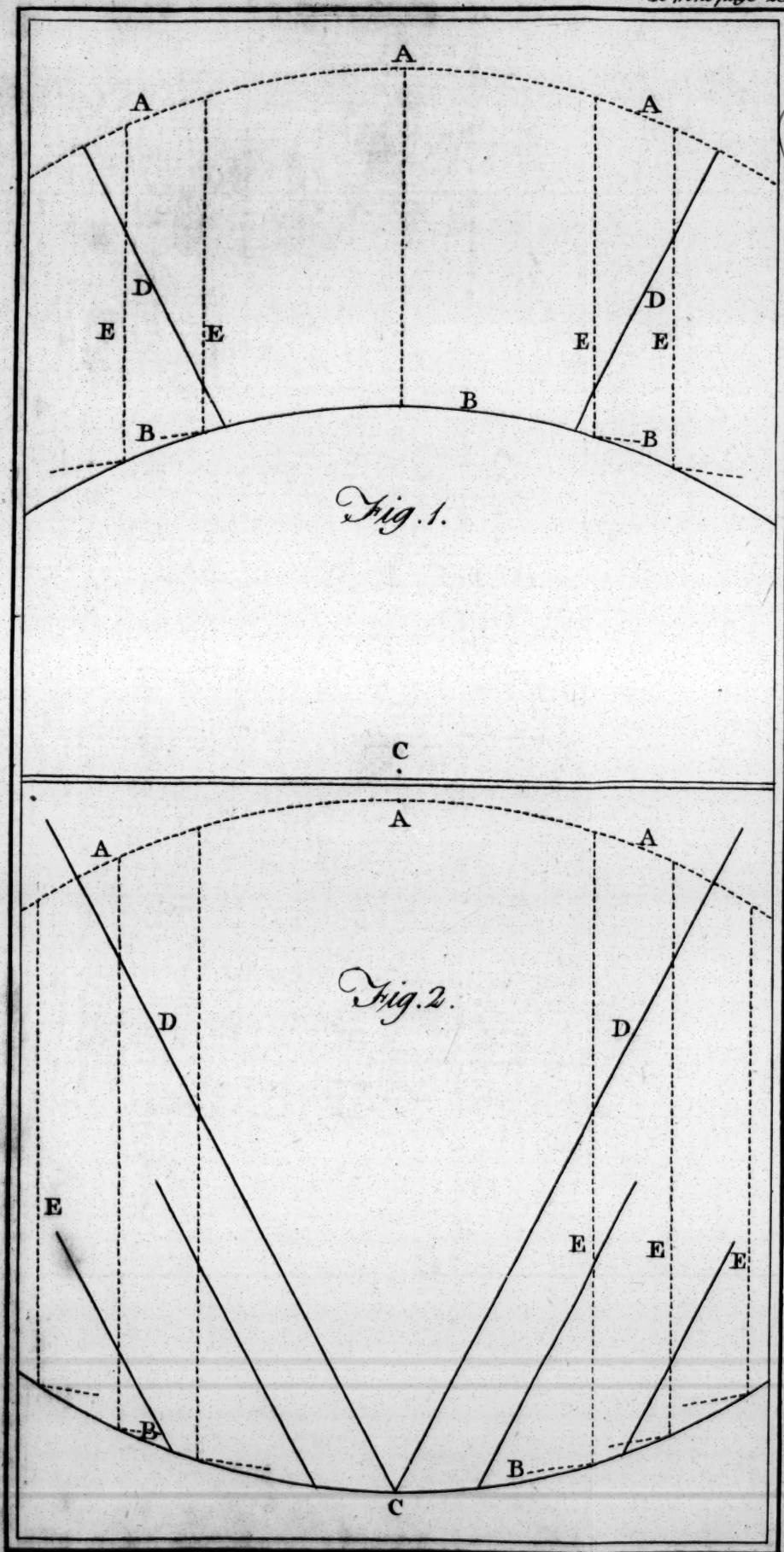
Wind, supposing it to blow across the Road, as it ascends the Ridge it is accumulated; and when reached the Summit, it's Motion is accelerated down the opposite Side, and it's Power increased, in a Ratio capable of Calculation; and in it's Course carries with it the finer and lighter Materials from the Road; and it may be found that on such a Construction, in the Course of a Year, the Sides will be lower, in Proportion to the upper Part (even Independent of wearing) than it was in the Beginning. The various Directions of Winds, will have proportional Effects. The Reason of this false Mould of a Road is pleaded, *to give Allowance for the unavoidable Sinking of the higher Parts.* To this it
may

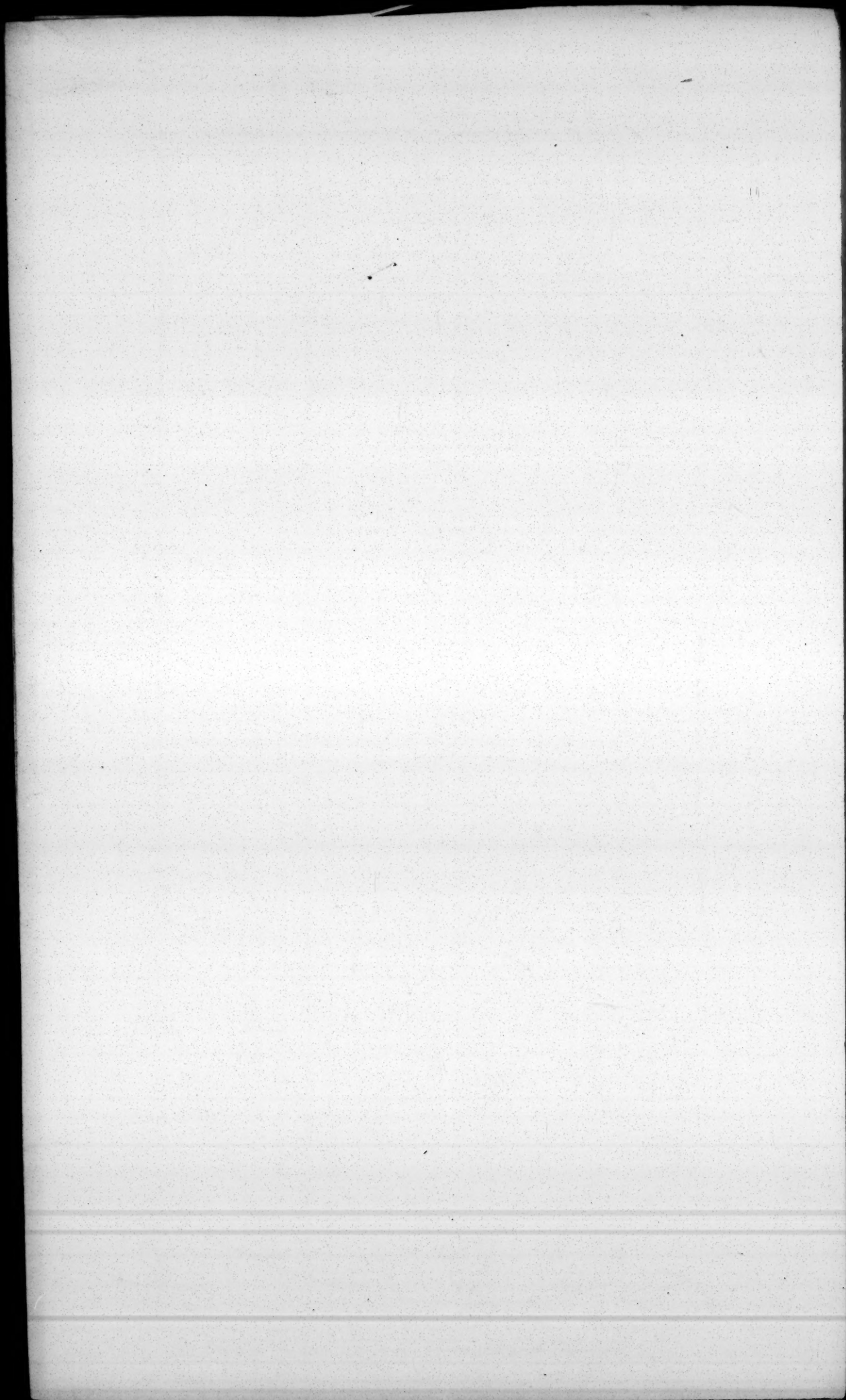
may be answered, that if, after the Foundation is formed, proper Time was allowed, for the several Parts to subside thoroughly, and to find their respective Gravities before the upper Materials are laid on, the future Depressions would be but small, and what Parts might happen to fall in, might be easily filled up, as they appear; whereas in the former Case, if any of the Parts of superior Density or of a different Quality, pierce deep into the Foundation, they will there form an unequal ranged Mass, which perhaps might not henceforward lye in equally poised Manner.

Another Objection which arises against a Road being raised high is,
that

that from it's elevated Shape it's Surface, at certain Seasons, may be too much exposed to Exhalations, from Sun and Air, and may thereby be too dry: This may occasion Dust to rise, disagreeable as well as a Consumption of the Road; side Trenches may have a like Effect in some Cases; and back Drains may be more proper.

The Method of forming Roads usually practised, is to dig the Trenches of each Side, and to throw their Contents on the Surface of the intended Foundation, thereby making it from the First to swell and to be Circular. On this they put the covering Gravel, which still makes it more





more so ; and, in Fact, joins two
Arches one upon another.

A few Observations on this Mode,
may not be unnecessary.

It is presumed, it will be granted,
that an Arch formed of various Sub-
stances, compacted and cemented to-
gether, has for it's Center of Gravity
the Center of the Circle, of which
it is a Section ; yet, before the several
constituent Parts are joined together,
so as to act as one Body, each of them
must retain it's own native Power,
and must gravitate in the perpendicular
Line.

E

Such

Such is the Situation of a Road newly gravelled and not yet begun to bind; here Nature exerts two different Laws, Gravity, and mutual Cohesion of the Parts, yet diverse in their Operations; the former in perpendicular Descent; the latter flow, with a forced Endeavour by Attraction to find out the Center of the Circle. Gravity preponderates, counter-acts the other, and strives to wrench it from it's intended Purpose.

This may be more fully illustrated from the annexed Draught, Fig. 1. where the dotted Circle AA represents the Covering of Gravel of the Road; BB the formed Foundation; C the Center of the Section of these
two

two united Arches; DD the Lines proceeding from thence to the Circumference; and EE the Lines perpendicular to the Plane of the Horizon. In these perpendicular Lines EE each Particle of Matter must descend from it's own Weight, till it finds a steady fixed Base to stop it's Progress; and these Lines are seen to deviate from Right to Left, from the Middle of the Road, in Directions different from the Lines DD which terminate in C the Center of Gravity of the Arch A, where the Tendency must be, when the attractive Cohesion of the various Parts takes Place.

As it has been shewn above, that the Gravel must proceed to the Foun-

dation, in Lines towards each Side of
 the Road, from the Middle of it even
 from the Density of the Parts; it will
 still continue to move in these Direc-
 tions with more Violence and Velo-
 city, when it comes to be unequally
 pressed by Weight. When the Gra-
 vel reaches the Foundation (either
 partially, or in a Continuity of pro-
 gressive Motion) they find it rounded,
 and the Parts fall upon a circular in-
 clining Base, in an oblique Angle,
 and are still more forced towards
 the Edges of the Road; and partly
 must be thrown into the Ditches,
 whereby the Road is robbed, and al-
 so hindered from binding; the per-
 pendicular Gravity, and the cohesive
 Search after the Center of the Arch,
 being

being counteractive Propensities, may perhaps, for ever deprive the Materials from finding their proper Place of Rest; they lie open to Rains, and each Side moulders away, only leaving the middle Part standing up with a high Back.

As the Surface of a Road must be somewhat rounded to throw off the superfluous Wet from Rains; and since such untoward Consequences seem to follow from the Manner of forming as above described; it appears agreeable to the Laws of Nature to have an opponent Power which may divert these, and by a contrary Exertion to constitute another, which may not only prevent the Parts from
 assuming

assuming a wrong Bias, but will even incline them towards the Center of cohesive Gravity.

Suppose, that whatever is the Curve of the Surface of a Road, a similar inverted Curve is made in the Foundation Part lying under it. The Effects will be, as the following Sketch exhibits, Fig. 2. where AA represent the Surface of the Road gravelled; BB the Foundation; C the Center of the Circle; DD Lines proceeding from thence to AA; EE Perpendiculars to the two Planes of the Arches AA BB.

Were dense elastick Bodies supposed to fall with Velocity in the Directions

EE

EE upon an inclined Segment of a Curve equally to B, they would recoil from thence, in Angles proportionate to the Angles of Incidence. Such is not asserted to be precisely the Consequence of a Quantity of mixed Matter descending by it's own Weight: Yet assuredly, when this Matter is impelled by Pressure, (as by Repair of Carriages, &c. on a Road) and meets with Resistance from the Foundation, it must endeavour to recoil and leave the perpendicular Direction.

The Tendency of this new acquired Motion will be towards the central perpendicular Line of the inverted Arch; the two diverging Directions
of

of Gravity, and of the Tendency to the Center of the Arch, will now both conspire in the Purpose demanded; the whole Mass of Matter of each Side will be forced inwards to the Center; as it will be hemmed in, by the circular Declivity of the Sides of the Foundation, and compact the various Parts of the Road into one united solid Body; and the more it is occupied in dry Weather, the sooner will this be effected.

It may not be improper to mention, that for the sake of more obvious Demonstration, the Road has been represented in the above Draughts, to be the Section of a perfect Circle; in which the opposite Powers and Propensities

penfities of Matter must act with the widest Difference ; still as the Surface of a Road must be somewhat circular or swelling, the Consequences must be fimilar, though in a less Degree, as they approach nearer to a flat Surface. The Materials of the Gravel-ling Part, are also supposed be homogenous, and to act as complete Spheres in an uninterrupted Course. Though these Circumstances can never happen literally ; yet, it became necessary to conceive them so, in order to investigate the great Out-lines of the Properties of Gravity, &c. Gravel, though generally not perfectly round, will however act comparatively so, and may be fairly reasoned upon with Allowances.

F

Let

Let the ingenious Mind trace out the principal Features; these it keeps in View, and can apply Resemblance wherever found. Many may be the Varieties, yet Nature's Laws are permanent and must be obeyed; the discerning Eye perceives their Energy, though from the narrow Limits of the human Soul, their secret Operations and specific Qualities, may be too minute and mysterious for exact Calculation.

It is presumed, that to an intelligent Observer, the Form of a Road described above, may appear to be (from it's Construction) the most stable and durable; the Execution is easy and simple, where the Situation
and

and the Funds answer. It may be somewhat more Expensive in making, yet after a Course of seven Years it may turn out the cheapest.

The Cost also may be lightened, provided the neighbouring Farmers should think it their Interests, to scoop out the valuable Soil from the hollowed Foundation at their own Charges, to make Composts, or raise Inclosures on the Sides of the Road; it may save the Expence too of digging side Trenches.

After all it must be acknowledged, that as it will require more Gravel than in the common Method; if this should lie at any considerable distance,

there are few public Funds, and fewer public Spirits, that are able and willing to bear, or to risque the Chance of Losses ; still the Subject is of that Moment, as to merit an Enquiry into the Practicability on the one Side, and to call forth Exertion on the other.

In difficult and perplexing Situations, Taste and Intelligence in Nature (as pointed out above) must finally direct : These will teach the making the best Use of such Materials as they can command ; they will study with Accuracy the Diversities of Soil, and Shape of Grounds they have to deal with ; and will avoid such Absurdities as Ignorance daily furnishes melancholy

choly Instances of: Much Money
funk, and much bad Travelling.

Gravels and Earths require a certain
Degrée of Moisture, to give them So-
lidity; it tends to increase the Cohe-
sion or Attraction of the Parts, as well
as by it's propensive or repelling Power,
to form Resistance against Pressure:
Sand in a dry, or in a moist State,
shews these different Effects.

If a Road in the Summer Months
could be dissected, it would be found
full of Cracks from the unequal Con-
traction of it's Parts; how weakening
is this to it's Fabrick; into these Fis-
sures succeeding Rains enter; and these
little Basons are seized on by Frosts,
and

and the surrounding Parts are rent and crumbled down by Thaws : Whereas, when Drains are properly adjusted, and the Surface but just rounded, the superfluous Water gently falls off, and no more is imbibed than what the Earths naturally lay hold of and can retain, and the Pores are compactly filled, and the entire Stratum, united upon a firm Base; and when proper Moisture is not to be had from the Clouds, it will be drawn up from the Foundation.

To think of making a Road entirely, or any Part of it, of large Stones is an Undertaking contrary to the proportionate Laws of Matter, from whence the above Observations are attempted

attempted to be deduced; and this from their superior Weight piercing into the Foundation, where there is no adequate Resistance; from their continued Inclination still to descend and their never finding that self Poise, that counteractive State, so essential to Duration. They also from over pressing the Bottom-part, force up Water from thence, in such Quantities, as is hurtful to the Binding of the Road, as well as unpleasant to the Traveller: This has been experienced in Pavements, where the Stones are laid in a Course of Sand, but remedied by mixing a little Lime with the Sand with which it unites, and keeps down the rising Wet. Stones may be found to attract Moisture of themselves too, especially
if

if they be what is called *Land Stones*. Even when Stones are broke very small (which is expensive) their angular Shape cannot coincide with the above established Principles.

The only Method, any how plausible, is to hollow out the Foundation of the Road; and in this to build a Layer of Stones in the Form of an inverted elliptick Arch, and to fill this with those, beat fine as possible. These two Bodies may form a united Force, (though not a durable one) and may have somewhat of the Strength of a *complete* Ellipse; but this Scheme would cost so much, as to forbid trying it, unless from an absolute Necessity; besides, it is presumed,

sumed, that where Stones are, Gravel may not be far off. Perhaps in some Cases it might be found more expedient to have the Foundation formed in a right Angle, or even more acute ones, which might give the upper Materials the Power of a Wedge, and incline the superfluous Wet to subside more easily ; with other Advantages, which may be collected from Hints.

But these, with various other Experiments, ought first to be tried on a small Scale, such as in gravel Paths in Pleasure Grounds ; where at a trivial Expence, the Properties and Powers of Matter might be ascertained.

G

The

The minute Particles of different Substances, generally possess different Powers of Attraction towards each other; they will quit the weaker and fly to the stronger. These Powers are not only discovered in the various Solutions, but are likewise manifest in Bodies in their drier Forms; some unite closer (and as Road Makers term it) bind harder, Cements evince this; nay, strong Concretions and Putrefactions, in their several Stages, shew this great Work of Attraction to be for ever carrying on in the Bowels of the Earth.

What a Field for Ingenuity may present itself at a Gentleman's Door, in searching into the cohesive Qualities

ties of the many different Kinds of Gravels, Earths, &c. To enquire which of them unite best together in all their varied Combinations. To gain something of a Line to walk by, and to be able (from Mixtures) to use some Ingredients with Success, which in the common loose Way of Management, are reckoned totally unfit for their Purposes.

To point out Probabilities would lead into a large and deep Detail. They will occur to the *Naturalist*: To such it might appear impertinent to *others* unintelligible, fanciful or ludicrous.

As rolling seems so necessary for Roads, both in the Course of making and in the several Repairs, as well as to preserve them in good Order; might not each Parish be provided with a Roller, which might be used in the proper Seasons from the Statute Labour?

F. I. N. I. S.



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